Proceedings of the Iowa Academy of Science

Volume 62 | Annual Issue | Article 75

1955

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Weather Factors and the Timing of Evening Roosting Flights of Grackles and Starlings at Ames, Iowa

By John C. W. Bliese

Introduction

For a number of years, during the summer and fall months, thousands of bronzed grackles, *Quiscalus quiscula,* and starlings, *Sturnus vulgaris,* have come from the surrounding countryside each evening to roost in the shade trees in residential areas of Ames, Iowa. Regularly associated with them have been lesser numbers of cowbirds, *Molothrus ater,* and robins, *Turdus migratorius.* Beginning with preliminary observations in 1949, the roosting flights of these birds, as well as the features of their roost, were kept under observation until late 1952. Results of the observations on the roost have been given in Bliese and Hendrickson (1952), and Bliese (1953a and b, 1954a and b). This paper concerns the roosting flights only, and confines itself to those of the grackles and starlings.

During the years of the investigation, and presumably for a number of years prior to that, the birds came to the roost area along four more or less definite pathways or flight lines, one each from the east, south, southwest, and north. Each group or flight of birds was named after the direction from which it arrived. The southwest and north flights are of primary interest herein.

Although some observations were made beyond the city limits of Ames, most of them were confined to places within a few city blocks of the roost area. Locations were chosen where a broad expanse of sky was available and where experience showed that the flights, for the most part at least, were visible. At these spots the birds were on the last stage of their daily trips to the roost, and the flights were fully formed or organized. Little was seen of the manner in which smaller flocks converged to form larger flocks, as described by Jones (1897) and others.

Shortly after the investigation began it was noted that the time of arrival of any one flight was somewhat variable. Since it was obvious that the birds came earlier on dark days than on clear, weather elements were suspected as the cause. During 1951 and 1952, therefore, data on the more readily measurable weather factors were collected on the days that the flights were observed. These data included: brightness of the sky at zenith, per cent of cloudiness, temperature, relative humidity, wind direction, wind velocity, evening barometric pressure, barometric pressure change during the day.

Methods

To establish the timing of the flights, the evening observations were divided into 10-minute intervals that began on the hour, and the numbers of birds to arrive during each interval were determined. For purposes of the investigation the flight was said to have arrived at the mid-point of that 10 minute during which the largest number of birds arrived, and such arrival times were compared with sunset times as given in Hansen (1951). Numbers were obtained by actual counts when flocks were small, or by estimating by 5's, 10's, or 100's when the birds were more numerous. A multiple-unit tally counter, each unit assigned to a different species of bird, was used to keep track of the estimations, and the totals were recorded at the end of every 10 minutes.

Wind velocity was always measured at shoulder level with a Biram anemometer shortly before a flight began to arrive, and again after the flight was over. Temperatures were read on a metal-protected photographic thermometer that had been checked against good quality mercury thermometers, and relative humidity readings were obtained from a Serdex Hygrometer, Model 201, that was guaranteed to be accurate within one and a half per cent. The per cent of sky covered by clouds was estimated at the beginning and end of daily observations, and at intermediate times when necessary. Zenith light, in foot-candles, was obtained in the open with a Weston Sunlight Illumination Meter, Model 756. The sensitive element was readily pointed to zenith by being supported on a wooden paddle equipped with two bubble levels at right angles to each other.

The light meter usually was supported on the end of an orange crate, while the hygrometer and thermometer were placed on a shorter box next to it so as always to be in its shade. Temperature, relative humidity, and zenith light were recorded at the end of every 10 minutes, and intermediate values for them, as well as for wind velocity, were obtained by interpolation. Time was kept with a 17-jewel Swiss wrist watch that was always checked against radio time before going in the field. Barometric pressures were obtained from a barograph kept in operation at ground level in a school office. Changes in barometric pressure were those between 6:00 A.M. and 6:00 P.M.

Results and Discussion

The method of linear multiple regression was used to estimate the influence of the weather variables on the time of arrival of peak numbers of birds. Wind direction was omitted from the statistical analysis because preliminary study of the records indicated that, at least for winds of the velocities observed, it had little effect on the timing of the birds. Time of year, however, seemed to be related, and was included. Because of relatively few data obtained in 1952, and on the assumption that the behavior of the birds on any one flight was probably comparable in successive years, the records for 1951 and 1952 were combined to give 21 observations for grackles of the southwest flight, 21 for grackles of the north flight, and 36 for starlings of both flights together.

Table 1 gives the data obtained for grackles of the southwest flight, and Table 2 summarizes the statistical analysis thereof. In like manner Tables 3 and 4 tell the story for grackles of the north flight, and Tables 5 and 6 for starlings of both flights combined.

The upper portion of Table 2 gives the results of all eight variables, shown in Table 1, entered in the computations. Only the per cent of cloudiness has a regression coefficient that gives a significant t-test, but several other variables have moderate-sized t-values. In the second part of the table are the results of the computations in which only the four variables with the highest t-values in the first test are used. Now time of year shows up as significant at the 5 per cent level, and both per cent of cloudiness and wind velocity are significant at 1 per cent. The multiple correlation coefficient, R, decreases only from 0.886 to 0.881 as a result of deleting four variables, evidence that they affected the birds' responses very little. When the change in barometric pressure is next deleted, and the coefficients recomputed, the remaining variables give tests of significance in the same order as before, and R decreases but little. The last step, in which time of year is omitted, causes R to drop considerably more than in any prior test. Apparently that variable should be left in the list of consequential factors.

Thus, as far as the grackles of the southwest flight were concerned, the times of arrival of their peak numbers were affected primarily by wind velocity, cloudiness, and season. The appropriate regression equation is the third one of Table 2. It indicates that the time of arrival, in terms of minutes to sunset, decreased with the advancing season, increased with cloudiness, and increased with higher wind velocities.

A similar procedure of testing is outlined in Table 4 for grackles of the north flight. Because of experience with regression equations for the southwest flight, only five variables were entered in the computations: time of year, zenith light, cloudiness, wind velocity, and changes in barometric pressure, and only these variables are listed in Table 3.

As the first portion of Table 4 indicates, zenith light gives a very significant t-test, and wind velocity tests significant. Time of year and changes in barometric pressure have very low t-values. R is

Table 1

Weather data and the times of arrival of peak numbers of grackles of the southwest flight

	Date	X_1 Day of flight season*	X_2 Zenith light in foot-candles	X_3 Per cent of cloudiness	X_4 Temperature in degrees Fahrenheit	X_5 Per cent of relative humidity	X_6 Wind velocity in feet per minute	X_7 Barometric pressure at 6 P.M. in inches	Barometric pressure change (6 A.M. pressure minus 6 P.M. pressure)	X_8 Pressure change adjusted for sign	Minutes to sunset	Y Minutes to sunset adjusted for sign
1951												
June	21	15	785	100	65.0	80.5	588	28.910	-.050	.150	34	39
July	10	34	738	25	66.0	74.5	473	29.125	.075	.275	23	28
	11	35	178	100	66.0	88.5	440	29.110	-.010	.190	43	48
	31	55	290	0	77.5	64.4	176	29.075	.000	.200	-2	3
Aug.	17	72	310	15	64.5	82.5	102	29.125	.000	.200	2	7
	18	73	202	5	69.0	80.5	22	29.160	-.015	.185	-5	0
	19	74	355	15	70.0	84.5	82	29.100	-.040	.160	4	9
	20	75	455	50	68.5	85.0	604	28.975	-.100	.100	12	17
	21	76	225	0	60.5	84.0	128	29.160	.030	.230	-4	1
	22	77	390	85	64.0	73.1	37	29.260	-.005	.195	4	9
	23	78	680	65	68.0	79.0	345	89:240	-.080	.120	13	18
	24	79	140	100	62.5	86.0	290	29.150	-.075	.125	6	11
Sept.	11	97	495	5	80.0	75.0	769	28.725	-.095	.105	7	12
Oct.	1	117	220	0	74.5	73.5	213	28.850	-.110	.090	3	8
	3	120	640	0	71.0	67.0	283	28.700	.050	.250	5	10
	24	141	290	0	54.0	65.0	477	29.090	-.090	.110	3	8
1952												
July	8	32	400	0	62.5	86.0	114	29.230	-.040	.160	3	8
Aug.	4	59	345	20	61.0	75.0	47	29.080	.070	.270	3	8
Sept.	1	87	340	40	57.0	76.0	183	29.075	-.030	.170	4	9
Oct.	4	121	375	100	51.0	28.0	561	29.140	-.040	.160	18	23
	31	148	350	75	62.5	28.5	107	29.090	.100	.300	8	13

*For purposes of this tabulation June 7 was taken as day number 1 in both years.

0.816. Results of the second portion of the testing, with time of year and change in barometric pressure omitted, show almost the same multiple correlation coefficient, R, obtained when the two factors were included in the computations. Zenith light tests significant at 1 per cent, as before, and wind velocity now tests significant at 1 per cent rather than at 5. When zenith light is next excluded from the computations, as shown in the third portion of Table 4, R drops from 0.815 to 0.651. None of the standard partial regression coefficients now test significant, though the t-value for cloudiness is not far from the 5 per cent level of probability. Next, with

Table 2

Regression of flight peak time, in minutes to sunset, on time of year and weather factors for grackles from the southwest

Variables (21 observations)	Standard partial regression coefficients	t	R
X_1 Time of year	-.3382	1.30	0.886
X_2 Zenith light in foot-candles	-.0202	0.11	
X_3 Per cent cloudiness	.5278	3.00*	
X_4 Temperature in degrees Fahrenheit	-.0489	0.25	
X_5 Relative humidity	.0491	0.19	
X_6 Wind velocity in feet per minute	.5052	2.11	
X_7 Barometric pressure in inches	-.1371	0.59	
X_8 Change in barometric pressure from 6 A.M. to 6 P.M.	.2406	1.14	
$\hat{Y} = 316.3024 - 0.1139X_1 - 0.0013X_2 + 0.1574X_3 - 0.0826X_4 + 0.0357X_5 + 0.0273X_6 - 10.7521X_7 + 47.3973X_8$			
Omitting X_2, X_4, X_5, and X_7			
X_1 Time of year	-.3281	2.74*	0.881
X_3 Per cent of cloudiness	.4821	3.87**	
X_6 Wind velocity in feet per minute	.5616	4.06**	
X_8 Change in barometric pressure	.2336	1.75	
$\hat{Y} = 8.2937 - 0.1105X_1 + 0.1438X_3 + 0.0304X_6 + 0.0562X_8$			
Omitting X_2, X_4, X_5, X_7, and X_8			
X_1 Time of year	-.3412	2.70*	0.856
X_3 Per cent cloudiness	.4990	3.80**	
X_6 Wind velocity in feet per minute	.4520	3.46**	
$\hat{Y} = 10.1687 - 0.1149X_1 + 0.1488X_3 + 0.0245X_6$			
Omitting X_1, X_2, X_4, X_5, X_7, and X_8			
X_3 Per cent cloudiness	.5434	3.59**	0.786
X_6 Wind velocity in feet per minute	.4388	2.90**	

*Significant at P = .05
**Significant at P = .01

both zenith light and barometric pressure change omitted, R drops but little, but cloudiness and wind velocity test significant at 5 per cent. When time of year is next dropped, R changes only slightly.

Everything considered, the second portion of Table 4 gives the regression statistics for the factors of greatest influence on the birds' time of arrival at the roost. Zenith light and wind velocity both test significant at the 1 per cent level, as noted above, and per cent of cloudiness has a probability of about 6 per cent. The corresponding regression equation shows that the minutes to sunset, for peak numbers of grackles, increased with the amount of zenith light present, with the per cent of cloudiness, and with wind velocity, for all regression coefficients have a positive sign.

Table 3

Weather data and the times of arrival of peak numbers of grackles of the north flight

Date		X_1 Day of flight season	X_2 Zenith light in foot-candles	X_3 Per cent of cloudiness	X_4 Wind velocity in feet per minute	Barometric pressure change (6 A.M. pressure minus 6 P.M. pressure)	X_5 Pressure change adjusted for sign	Y Minutes to sunset
1951								
June	25	19	1055	75	423	-.265	.035	45
July	18	42	765	50	154	-.020	.280	19
	19	43	905	90	263	-.080	.220	28
	20	44	645	0	610	-.175	.125	17
	21	45	708	10	531	.080	.380	27
	22	46	880	30	137	.010	.310	26
	23	47	555	0	48	-.030	.270	15
	24	48	587	10	80	-.060	.240	14
	25	49	660	0	61	-.035	.265	13
	26	50	470	25	114	-.090	.210	13
	30	54	1315	95	248	-.070	.230	19
Aug.	2	57	592	90	59	-.020	.280	15
	13	68	740	40	74	.025	.325	22
Sept.	6	92	470	10	46	.070	.370	5
	7	93	1250	98	124	-.030	.270	33
	8	94	1130	95	533	-.170	.130	32
	24	110	320	100	433	.050	.350	25
Oct.	18	135	550	100	264	.065	.365	27
1952								
July	9	33	695	0	205	-.100	.200	13
Aug.	5	60	2000	80	70	.040	.340	32
Sept.	4	91	1700	0	399	-.090	.210	38

Data for starlings of the southwest and north flights were combined, for preliminary examination of the records seemed to indicate rather similar behavior. Because some of the weather variables proved to be of negligible significance to the grackles, the assumption was made that they were probably equally unimportant to the starlings. Consequently only five variables were used and tested by the method of multiple regression, the same five as used for grackles of the north flight. These data are tabulated in Table 5, and the results of the analysis are in Table 6.

Table 4

Regression of flight peak time, in minutes to sunset, on time of year and weather factors for grackles from the north

Variables (21 observations)	Standard partial regression coefficients	t	R
X_1 Time of year	.0079	0.04	0.816
X_2 Zenith light in foot-candles	.5175	3.30**	
X_3 Per cent cloudiness	.2965	1.74	
X_6 Wind velocity in feet per minute	.3865	2.23*	
X_8 Change in barometric pressure	-.0569	0.29	
$\hat{Y} = 5.7081 + 0.0027X_1 + 0.0121X_2 + 0.0705X_3 + 0.0208X_6 - 6.3267X_8$			
Omitting X_1 and X_8			
X_2 Zenith light in foot-candles	.5268	3.63**	0.815
X_3 Per cent cloudiness	.2939	2.02	
X_6 Wind velocity in feet per minute	.4099	2.90**	
$\hat{Y} = 3.8034 + 0.0123X_2 + 0.699X_3 + 0.0220X_6$			
Omitting X_2			
X_1 Time of year	-.0025	0.01	0.651
X_3 Per cent cloudiness	.4283	2.03	
X_6 Wind velocity in feet per minute	.3749	1.70	
X_8 Change in barometric pressure	-.1553	0.63	
$\hat{Y} = 17.7491 - 0.0009X_1 + 0.1018X_3 + 0.0201X_6 - 17.2756X_8$			
Omitting X_2 and X_8			
X_1 Time of year	-.0862	0.42	0.640
X_3 Per cent cloudiness	.4516	2.22*	
X_6 Wind velocity in feet per minute	.4434	2.36*	
$\hat{Y} = 13.9896 - 0.0295X_1 + 0.1073X_3 + 0.0238X_6$			
Omitting X_1, X_2, and X_8			
X_3 Per cent cloudiness	.4178	2.28*	0.635
X_6 Wind velocity in feet per minute	.4390	2.40*	

*Significant at $P = .05$
**Significant at $P = .01$

In Table 6, as in Tables 2 and 4, the successive blocks show the statistics obtained by deleting certain variables, and the second block shows the variables which apparently were of most consequence to the starlings. By comparing the first block with the second, it can be seen that deleting wind velocity and change in barometric pressure causes R to decrease only from 0.785 to 0.765. The first three variables predict the minutes to sunset almost as well as all five.

Although time of year does not test significant in the second portion of Table 6, its t-value is not far from the 5 per cent level,

Table 5

Weather data and the times of arrival of peak numbers of starlings of the southwest and north flights

		Date	X_1 Day of flight season	X_2 Zenith light in foot-candles	X_3 Per cent of cloudiness	X_6 Wind velocity in feet per minute	Barometric pressure change (6 A.M. pressure minus 6 P.M. pressure)	X_8 Pressure change adjusted for sign	Y Minutes to sunset
Southwest flight									
1951	June	21	15	785	100	588	-.050	.250	34
	July	11	35	178	100	440	-.010	.290	43
		31	55	730	0	176	.000	.300	18
	Aug.	17	72	640	15	151	.000	.300	17
		18	73	745	5	35	-.015	.285	15
		19	74	1130	15	161	-.040	.260	24
		20	75	835	30	578	-.100	.200	22
		21	76	588	0	271	.030	.330	11
		22	77	390	85	37	-.005	.295	4
		23	78	680	65	345	-.080	.220	13
		24	79	330	100	288	-.075	.225	16
	Oct.	1	117	540	0	251	-.110	.190	13
		3	120	640	0	283	.050	.350	5
		24	141	290	0	477	-.090	.210	3
1952	July	8	32	515	0	137	-.040	.260	8
	Aug.	4	59	1850	80	119	.070	.370	43
	Sept.	1	87	870	50	259	-.030	.270	19
	Oct.	4	121	375	100	561	-.040	.260	18
North flight									
1951	June	25	19	980	50	443	-.265	.035	25
	July	18	42	1150	50	170	-.020	.280	39
		19	43	905	90	263	-.080	.220	28
		20	44	335	0	612	-.175	.125	7
		21	45	330	10	553	.080	.380	7
		22	46	520	40	115	.010	.310	16
		23	47	620	0	48	-.030	.270	15
		24	48	587	10	80	-.060	.240	14
		25	49	660	0	61	-.035	.265	13
		26	50	735	25	141	-.090	.210	23
		30	54	1315	95	248	-.070	.230	19
	Aug.	2	57	592	90	59	-.020	.280	15
		13	68	740	40	74	.025	.325	22
	Sept	6	92	730	10	65	.070	.370	15
		7	93	785	98	96	-.030	.270	23
		24	110	450	100	424	.050	.350	35
1952	July	9	33	1120	0	235	-.100	.200	23
	Aug.	5	60	2675	80	85	.040	.340	42

Table 6

Regression of flight peak time, in minutes to sunset, on time of year and weather factors for starlings from the southwest and north

Variables (36 observations)	Standard partial regression coefficients	t	R
X_1 Time of Year	-.2580	2.15*	0.785
X_2 Zenith light in foot-candles	.4874	3.92**	
X_3 Per cent cloudiness	.4185	3.54**	
X_6 Wind velocity in feet per minute	.1742	1.34	
X_8 Change in barometric pressure	.1563	1.24	
$\hat{Y} = 3.3478 - 0.0944X_1 + 0.0114X_2 + 0.1128X_3 + 0.0104X_6 + 24.3184X_8$			
Omitting X_6 and X_8			
X_1 Time of year	-.2162	1.86	0.765
X_2 Zenith light in foot-candles	.4559	3.86**	
X_3 Per cent cloudiness	.4595	3.97**	
$\hat{Y} = 11.4836 - 0.0791X_1 + 0.0107X_2 + 0.1238X_3$			
Omitting X_2			
X_1 Time of year	-.3496	2.45*	0.648
X_3 Per cent cloudiness	.5212	3.73**	
X_6 Wind velocity in feet per minute	.0267	0.18	
X_8 Change in barometric pressure	.1809	1.18	
$\hat{Y} = 14.2587 - 0.1279X_1 + 0.1405X_3 + 0.0016X_6 + 28.1454X_8$			
Omitting X_2 and X_8			
X_1 Time of year	-.3034	2.20*	0.628
X_3 Per cent cloudiness	.5427	3.90**	
X_6 Wind velocity in feet per minute	-.0432	0.31	
$\hat{Y} = 21.4103 - 0.110X_1 + 0.1463X_3 - 0.0026X_6$			
Omitting X_1, X_2, and X_8			
X_3 Per cent cloudiness	.5559	3.78**	0.550
X_6 Wind velocity in feet per minute	-.0655	0.45	

*Significant at $P = .05$
**Significant at $P = .01$

and when it is omitted from the computations in the last section of the table, it causes a considerable decrease in R, from 0.628 to 0.550.

The second regression equation in Table 6 indicates that the minutes to sunset decreased with the advancing season, and increased with zenith light and with per cent of cloudiness.

The zenith light conditions and the birds' response thereto deserve special comment. A limited cloud cover, especially if the clouds were near zenith, and light haze, caused higher readings on the light meter than did a clear sky. Only when the clouds were fairly extensive and thick did the light readings decrease when the per cent of cloudiness increased. Consequently the regression coefficients for zenith light turned out to have a positive value in each of the computations rather than a negative one as had at first been anticipated. Zenith light, for conditions obtaining during the investigation, seemed to be more of a measure of cloud formations and their location than of over-all light conditions caused by the angular altitude of the sun. It apparently made little difference to the birds where the clouds of a 10 per cent cloudy were located, but it made considerable difference on the light meter's response.

Summary and Conclusions

Time of the year and weather variables were studied for their effect on the daily time of arrival of peak numbers of bronzed grackles and starlings at their roost in Ames, Iowa, and the data were analyzed by the method of linear multiple regression. Data for two flights were analyzed separately for the grackles, but were combined for the starlings.

The analysis showed significant t-values for several of the coefficients computed for season and weather factors. In terms of minutes to sunset these variables had the following effects on time of arrival of the roosting flights: advancing time of year—a decrease for grackles of the southwest flight and for starlings; increasing per cent of cloudiness—an increase for all birds; increasing zenith light—an increase for grackles of the north flight and for starlings; increasing wind velocity—an increase for grackles of both flights.

The coefficients which were obtained for time of year for grackles of the north flight, zenith light for grackles of the southwest flight, and wind velocity for starlings, all tested non-significant.

Evening barometric pressure, barometric pressure changes during the day, temperature, and relative humidity, all tested non-significant for all three groups of birds.

The location of clouds, if only a few were present, had no apparent effect on the time of arrival of the birds, but it had considerable influence on the light meter. When the clouds were overhead, higher readings were obtained than when the clouds were nearer the horizon. An estimate of per cent of cloudiness, and the readings of the meter pointed to zenith, therefore, did not necessarily give parallel measures of illumination. When clouds were more numerous, however, an increase in cloudiness was always accompanied by a decrease in the foot-candles read on the meter.

Acknowledgements

The writer wishes to express a word of thanks and appreciation to Dr. George O. Hendrickson, Professor of Zoology, for directing the investigation, and to Mr. Paul G. Homeyer, Professor of Statistics, for his help on the statistical phases of the work. Both men are on the Iowa State College faculty.

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